SINGULATION METHOD AND RESULTING DEVICE OF THICK GALLIUM AND NITROGEN CONTAINING SUBSTRATES

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Application No. 61/356,478, filed Jun. 18, 2010, which is incorporated herein by reference for all purposes.

BACKGROUND OF THE INVENTION

The present invention relates generally to lighting techniques. More specifically, embodiments of the invention include techniques for manufacturing optical devices, such as light emitting diodes (LEDs) using a separation process of thick gallium and nitrogen containing substrates, such as GaN configured in non-polar or semi-polar crystalline orientations. The starting materials can include polar gallium nitride containing materials. The invention can be applied white lighting, multi-colored lighting, general illumination, decorative lighting, automotive and aircraft lamps, street lights, lighting for plant growth, indicator lights, lighting for flat panel displays, and other optoelectronic devices.

In the late 1800's, Thomas Edison invented the light bulb. The conventional light bulb, commonly called the "Edison bulb," has been used for over one hundred years. The conventional light bulb uses a tungsten filament enclosed in a glass bulb sealed in a base, which is screwed into a socket. The socket is coupled to an AC power or DC power source. The conventional light bulb can be found commonly in houses, buildings, and outdoor lightings, and other areas requiring light. Unfortunately, drawbacks exist with the conventional Edison light bulb. That is, the conventional light bulb dissipates much thermal energy. More than 90% of the energy used for the conventional light bulb dissipates as thermal energy. Additionally, the conventional light bulb routinely fails often due to thermal expansion and contraction of the filament element.

Solid state lighting techniques are known. Solid state lighting relies upon semiconductor materials to produce light emitting diodes, commonly called LEDs. At first, red LEDs were demonstrated and introduced into commerce. Red LEDs use Aluminum Indium Gallium Phosphide or AlInGaP semiconductor materials. Most recently, Shuji Nakamura pioneered the use of InGaN materials to produce LEDs emitting light in the blue color range for blue LEDs. The blue colored LEDs led to innovations such as solid state white lighting, the blue laser diode, which in turn enabled the Blu-Ray™ (trademark of the Blu-Ray Disc Association) DVD player, and other developments. Other colored LEDs have also been proposed.

High intensity UV, blue, and green LEDs based on GaN have been proposed and even demonstrated with some success. Efficiencies have typically been highest in the UV-violet, dropping off as the emission wavelength increases to blue or green. Unfortunately, achieving high intensity, high-efficiency GaN-based green LEDs has been particularly problematic. Additionally, GaN based LEDs have been costly and difficult to produce on a wide-scale in an efficient manner.

Conventional LED fabrication process typically employ a wafer scribing and breaking procedure to separate individual LED chips within a wafer. The wafers are typically thinned to ~100 um or less, and are typically laser- or diamond-scribed, on one side prior to dicing. Thinning often uses grinding and polishing techniques, which are time consuming and costly.

BRIEF SUMMARY OF THE INVENTION

The invention provides a method for singulation of thick GaN wafers (e.g., 300-400 um) through the use of a double-side laser-scribe process. In a preferred embodiment, the patterned GaN substrate is processed using a laser-scriber on each of the substrate surfaces to form scribe lines. The scribe lines are aligned to each other. The method is most useful on substrates not subjected to a thinning or polishing process for reducing a thickness of the substrate.

The invention provides a method for separating individual die from a substrate member comprising optical devices. The method includes providing a gallium and nitrogen containing substrate member having a plurality of optical devices, e.g., light emitting diodes, configured in an array. The substrate member has a front side and a back side. The method includes aligning a scribe device to scribe at least a street region on a portion of the front side between a first optical device and a second optical device and forming a first scribe line on the street region between the first optical device and the second optical device. The method also includes forming a second scribe line on a backside portion of the substrate member overlying the first scribe line while maintaining a thickness of the substrate member between the first scribe line and the second scribe line. Energy (e.g., mechanical, chemical, electrical,) is then applied to a portion of the substrate member to separate the first optical device from the second optical device.

In an alternative embodiment, the present invention provides a bulk GaN wafer with an overlying LED epitaxial structure and with p-type and n-type metallizations, fabricated such that there are 'scribe streets' separating individual LED devices on the wafer.

The LED wafer is laser-scribed within the 'scribe streets' on a first surface of the wafer, along one or more axes according to a specific embodiment. The scribe depth in the scribed regions on the first surface is typically 20-25% of the thickness of the LED wafer according to a specific embodiment. In a specific embodiment, the LED wafer is then flipped over, and is then laser-scribed within the 'scribe streets' on a second surface of the wafer, along one or more axes, taking care to ensure that the scribes on the second surface are aligned to be substantially overlying the scribes on the first side of the wafer. In other embodiments, scribe lines on one side may be aligned to scribe lines on the other side of the substrate In a specific embodiment, the scribe depth in the scribed regions on the second surface is typically 20-25% of the thickness of the LED wafer The scribed LED wafer is then broken using an anvil breaker setup. Breaking occurs along the planes defined by two aligned scribed regions on the two opposing sides of the wafer. In a specific embodiment, the present method allows for the singulation of thick GaN wafers, thereby eliminating the need for expensive and time-consuming lapping and polishing steps in the LED fabrication process.

The present method provides for the singulation of thick GaN wafers into individual LED chips with lateral chip dimensions that are significantly smaller than those enabled by standard single-sided scribe methods. In other embodiments, the present method provides higher process yields at the scribe and break process steps than conventional methods. Additionally, there is a reduced incidence of chip-outs, as well as doublets (pairs of chips that are not separated during the break step). In other embodiments, the scribed regions may induce surface roughening on the side-walls of the gen-